# A COMPREHENSIVE EVALUATION OF THE CLINICAL EFFICACY OF AQUA COOLANT INFLUENCING THE VARIATION IN PULPAL TEMPERATURE DURING TOOTH PREPARATION

**- AN IN-VIVO STUDY**

*Dissertation submitted to*

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**MASTER OF DENTAL SURGERY**

**BRANCH VI – PROSTHETIC DENTISTRY**

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# CERTIFICATE

This is to certify that the dissertation entitled as **"A COMPREHENSIVE EVALUATION OF THE CLINICAL EFFICACY OF AQUA COOLANT INFLUENCING THE VARIATION IN PULPAL TEMPERATURE DURING TOOTH PREPARATION - AN IN-VIVO STUDY"** done by **Dr. VINAMRA DHARIWAL** Post Graduate student, M.D.S, Branch VI – Prosthetic Dentistry, Saveetha Dental College and Hospitals, Chennai, submitted to The Tamil Nadu Dr.M.G.R. Medical University in partial fulfillment for the M.D.S. degree examination in September 2006, is a bonafide research work done under our guidance and supervision.

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Head of the Department,
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Chennai.

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Date :

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**Prof. Dr. A.Venkatesan,**
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Date :

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Compilation of this work is not an enterprise of a sole individual but a consolidated effort of a group of committed members who left no stone unturned for accomplishment of this endeavour. I owe them all with gratitude – ‘a heart felt thanks'.

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# INTRODUCTION

# A COMPREHENSIVE EVALUATION OF THE CLINICAL EFFICACY OF AQUA COOLANT INFLUENCING THE VARIATION IN PULPAL TEMPERATURE DURING TOOTH PREPARATION.

## - AN IN-VIVO STUDY

## INTRODUCTION

Dental pulp is an exuberant vital tissue, encased in a rigid dentinal matrix and is confounded with an extremely complex vascular network. Conventional clinical therapeutic dental procedures attempted, often generate thermal and mechanical stimuli of conspicuous magnitude capable of insulting and injuring the pulpal[2, 70], peripulpal[34] and the periapical[20] tissues. In prosthodontics the construction of a fixed partial denture invariably involves irreversible loss of tooth structure by means of tooth preparation strongly suggesting possibilities of thermal assault on pulp and surrounding tissues.

It is commonly believed that the elevation in temperature during the process of tooth preparation poses a serious threat to pulpal integrity and vitality.[2, 16,29,43,55,57,70,71] Even though intra oral temperature may fluctuate between 0° to 70°C in function[9]. Studies have shown that increase in the intra pulpal temperature by 5.5° C can cause irreversible pulpal damage in 15% of teeth.[71] However other authors have reported that despite a steep acceleration of intrapulpal temperature by 11.2°C[8], no detectable changes warranting presence of pulpal damage were observed and documented.

Preservation of the health and vitality of pulpal tissue by means of cooling the bur-tooth interface with water during tooth preparation has been an established procedure for decades. It was earlier inferred that heat generated by friction between mineralized hard tissues and rotating instruments could cause irreversible damage to the pulp. There have been various studies on alteration of intrapulpal temperature during various dental procedures inclusive of cavity and tooth preparation[1, 5,6,7,10,11,14,16, 17,20,22,28,32,43,44,45,46,47,49,55,56,58,70].Temperature, rate of flow, use and mode of delivery of coolant, speed of rotary instrument, pattern and grit of bur used or the technique executed influence the temperature alteration.

Amidst the various factors, which could control the elevation of temperature during tooth preparation, the use of aqua coolant (water) was rated supreme by the investigators. Very few in vivo studies have been conducted to assess the influence of aqua coolant in altering pulpal temperatures were attempted. Also the influence of aqua coolant at every stage of tooth preparation needed to be documented.

Hence this study was attempted to evaluate the temperature variation in the pulp chamber during crown preparation in the presence and absence of aqua coolant, with due consideration given to promulgate the various factors capable of altering temperature estimation viz, circulating blood flow, immediate tissue response to accommodate temperature variations and heat dissipation to adjacent tissues.

The **Aim and Objective** of this in – vivo study was to measure with improved accuracy, using the digital temperature indicator and thermocouple, in an exacting clinical situation:

a) The temperature variation observed in the pulp chamber during tooth preparation with the use of aqua coolant.

b) The temperature variation observed in the pulp chamber during tooth preparation without the use of aqua coolant

c) Evaluate and compare the advantage over temperature control offered by aqua coolant during every stage of tooth preparation.

# REVIEW OF LITERATURE

“ The only guide to what lies ahead is the study of past.”

In the persistent combat against edentulism the concept of fixed partial denture is an excellent counter offensive. But it still has its own repercussions. The process of fixed partial denture construction results in an irreversible loss of enamel and dentin and also challenges the sovereignty of the pulp.

Earliest documents in the Egyptian civilization (3000 BC) gives references regarding dental bridges retained with gold wire. Estrucians in 500 BC had fixed replacements of teeth with gold bands. In replacement of missing teeth with fixed partial denture using support of natural teeth was practiced as early as 400 – 500 BC in Phoenician civilization.

Mayan civilization by 300 - 900 A.D. used tube drills (of jade, copper as bur) and bow drills as rope driven rotary engines for preparing cavities. Eustachian (1563), studied pulp histology and blood supply. In sixteenth century 3 unit bridge made of bone supported by silver was used in France. Pierre Fauchard (1728) described various techniques for FPD fabrication by drilling adjacent teeth and deriving support from them. James Beall Morrison (1870) introduced the first foot treadle drill. George.F.Green (1872) introduced first electric power drill. Charles Henry Land (1903) described the technique for jacket crown. Nelson (1950) devised gearless water turbine with 60000RPM. Ivor Nelson (1952) designed a air turbine with 70,000RPM.Page Chayes (1958) invented first belt driven angled hand piece rotating 100000 RPM.

The friction developed at bur tooth interface may generate heat, which can either raise intra pulpal temperature or desiccate dentin. This problem becomes exponential with the use of ultra high speed, high torque air turbines. Use of coolants has been suggested to tame this problem.

This review gives us an insight on various studies related to temperature generation, pulpal histological response, factors influencing thermo genesis in tooth preparation and other dental procedures.

**HENSCHEL.C (1943),** [34] studied the impact of heat generated by revolving instruments on vital dentinal tubules. He had suggested that, as the dentin and enamel were good insulators. Most of the frictional thermal energy generated by bur contact is dissipated to the environment.

**POHTO M AND SHEININ A, (1957),** [61] observed microscopically the response of living dental pulp to heat. They have reported that an elevation in temperature from 37°C to 42°C resulted in vasodilatation and temperature at and above 44°C aggregates of RBC were formed. When temperatures at 46°C to 50°C were maintained for 30 seconds, thrombosis and cessation of blood flow would occur. The temperature of 41.8°C has been suggested as critical limit for pulpal fibroblast.

**HERBERT SWERDLOW, AND HAROLD R.STANLEY, JR., (1958)**, [35] studied the reaction of the human dental pulp to cavity preparation. An evaluation of the pulpal response was made in 53 sound human teeth in which cervical (Class V) preparations were prepared with an inverted cone tungsten carbide bur rotating at 150,000 r.p.m. All teeth were filled with zinc oxide and eugenol cement and extracted at intervals ranging from less than 1 hour to 132 days after cavity preparation. This operative procedure appeared to produce a mild, traumatic infiltration of leukocytes in the early phases of the experiment and the absence of intrapulpal abscesses and nodular formation of secondary dentine in the later phases. Observations concerning the phenomena of intra nuclear vacuolization of odontoblasts and increased eosinophilic staining were presented.

**STANLEY.H, SWERDLOW.H. (1960),** [63] studied the biologic effects of various cutting methods in cavity preparation. They suggested that the pressure alone plays a significant role in contributing to the incidence and intensity of the inflammatory response.

**HARNETT AND SMITH (1961),** [36] evaluated the production of heat in the pulp by the use of air turbine and found that the pulpal temperature dropped with the use of air coolant.

**ZACH AND COHEN (1962),** [70] studied on thermogenesis in operative techniques. The results of this study concluded that the washed-field technique, after clinically significant periods of drilling produces a total cooling effect on the pulp. Ultra high speed drilling, dry, using only air as the coolant, was contraindicated except for 5 to 10 second operative procedures. Un-cooled drilling produces a linear progressive intrapulpal temperature increase, which becomes critical after 20 seconds. On thermo genetic evidence, the washed-field technique appeared safest at all rotary operative speeds.

**FUNAKOSHI AND ZOTTERMAN (1963),** [26] conducted a in vivo study on excitation of dental nerve fibers. The intra pulpal temperature studied on dog teeth was found to be 35° C ± 0.5°C.

**BRADEN (1964),** [12] studied the thermal conduction in normal human teeth and gave the diffusion co-efficient of dentin as $1.8 \times 10^{-3}$ $cm^2$ /sec and thermal conductivity values of dentine as 0.0015 cal/sec/$cm^2$/°C.

**ZACH & COHEN (1965),** [71] studied pulp response to externally applied heat. Results of this study, indicated that healthy pulps at least in the species tested, failed to recover from an intrapulpal temperature increase of 20°F in about 60% of the cases. 15% of the teeth heated to 10°F failed to recover. Heat rises below this critical level produced reactions, relative in severity to the degree of heat, which almost invariably led to pulp recovery but left histological stigmata. Heat used above 20°F almost invariably destroyed the pulp.

**BHASKER et al (1965),** [11] studied the intra pulpal temperature during cavity preparation.  He found that pulpal temperature dropped when preparation was done in the absence of coolant.

**SCOTT AND STEWART (1965),** [58] studied the excitation of the dentinal receptor by heat on cat teeth .The intra pulpal temperature in this in vivo study was found to be 2°C ± 0.5°C lesser than the core body temperature.

**BEVERIDGE. E, BROWN A. (1965),** [19] studied the measurement of human dental intra pulpal pressure and its response to human variables. He demonstrated that grinding and drilling procedures produced increase in intrapulpal pressure.

**SCHUCHARD A, WATKINS CE (1965),** [57] conducted study on thermal and histological response to high-speed and ultra-high speed in cutting tooth structure. He reported that there was an increase in temperature of 4.4°C with air-cooling and decrease in temperature when water was used as coolant. Rotation of dental bur at ultra high-speeds produces an air “whirl” or “turbulence”. The rotating bur moves quantities of air in its immediate area, possibly dissipating heat. In addition, the coolant is probably acting on the entire tooth surface compared with the small contact area of the bur and the tooth. .

**ANDERSEN DL, MATTHEWS B (1967),** [3] studied on fluid flow through human dentin**.** He said that heat generated during cavity preparation could cause displacement of fluid from prepared surface, along with marked differences in osmotic gradients.

**BRANNSTOM M, LINDEN L (1968),** [13] studied the movement of dentinal and pulpal fluid caused by clinical procedures. He suggested that the movement of fluids from the pulp towards the tooth apex during cutting results from frictional heat of cutting causing fluid expansion.

**NYBORG (1968),** [51] evaluated pulpal reaction to heat. Heat was applied to dentinal floor of class V cavities in human volunteers. Heat of 150°C was applied for 30 seconds to dentin that had REMAINING DENTIN THICKNESS (RDT) of 0.5mm. The patients experienced no pain sensation in the heated teeth over the 30day period.

**BROWN W.S DEWEY (1970),** [15] analyzed the thermal properties of teeth. He gave the thermal diffusivity of bulk dentin to be 2.3x $10^{-3}cm^2$/sec.

**EVANS EA (1973),** [24] studied the analysis of fluid shear and micropipette deformed RBC and he concluded that heavy shear forces could disrupt cell membrane.

**ALFRED SCHUCHARD (1975),** [2] did a histological assessment of low-torque, ultra high -speed cutting technique. This study involving contra lateral teeth in individuals indicated insignificant differences in pulpal response to wet and dry cutting technique.

**FORSELL-AHLBERG K , EDWALL. L (1977),** [26] studied on the influence of local insult on sympathetic vasoconstrictor control in feline dental pulp. The vasoconstriction noted after cavities are prepared deep in dentin without a coolant may be due to inhibition of sympathetic nerve stimulation.

**CARSON J, RIDER T (1979),** [21] conducted a termographic study of heat distribution during ultra-speed cavity preparation. In his study he said that temperature increased by 2.8°C with air cooling and increased by about 0.48 to3.6°C with 45ml of water as coolant.

**W.W.BARKMEIER AND R.L.COOLEY (1979),** [10] studied on temperature changes caused by reducing pins in dentin. The pin temperature increase (heat generation) was prevented by an air-water coolant. Pin height adjustment with an ultra-speed instrument using air-water coolant produces no potentially injurious heat generation.

**R KERSCHBAUM, VOSS (1979),** [40] found that 10 years after crown placement 9.1% of these teeth that were subjected to thermal stimulus were not vital and 5.5% recorded only an equivocal reaction.

**R.L.COOLEY AND W.W.BARKMEIER (1980),** [22] studied on temperature rise in the pulp chamber caused by twist drills .The twist drills created a temperature rise in the pulp chamber up to 9 and 10$^{o}$F during several of the tests which could be a significant change in temperature and cause damage to the pulp tissue. Pin channel preparations with twist drills have the potential to produce a temperature increase in the pulp chamber. This temperature increase is related to twist drill diameter, length (depth of channel preparation), and rotational speed.

**STANLEY (1981),** [64] studied the human pulpal response to restorative dental procedures. According to his study poor thermal conductivity of dentin could result in thermal burns to surfaces to dentin without much change in pulpal temperature.

**GUNNAR BERGENHOLTZ AND STURE NYMAN (1983),** [33] studied on endodontic complications following periodontal and prosthetic treatment of patients with advanced periodontal disease. A retrospective analysis was carried out to determine the frequency and onset of endodontic complications occurring in 52 patients treated for advanced periodontal disease. Comparisons were made between teeth which, following periodontal treatment, were used as abutments in fixed prosthetic reconstructions and nonabutment teeth. The study included 672 teeth with initially vital pulps (255 abutment teeth and 417 nonbutment teeth (15% vs.3%). The majority of these lesions did not appear until several years following the completion of active treatment. Conceivable reasons for the development of pulpal necrosis in teeth subjected to combined periodontal and prosthetic treatment are discussed.

**O.J GRUSSER et al (1985),** [32] studied the changes in pulp temperature during thermo stimulation of human teeth by simple electrically controlled thermode and concluded that the temperature change at the cornu of the pulp measured in the in vitro experiments might be some what higher than in the in vivo test.

**SPIERINGS.TA (1987),** [62] did the verification of theoretical modeling of heat transmission in teeth. This in vitro experiment concluded that dentin is excellent insulator and a very poor conductor.

**HAROLD E. GOODIS et al (1988),** [29] studied on temperature gradients at two locations within the tooth cavity preparation in vitro. When no coolant was used an instantaneous rise in temperature occurred at the Pulpo Dentinal Junction (PDJ) to a peak of 10°C in the first minute followed by a sharp decline to the second minute, and a gradual decline thereafter. The temperature rise at DEJ was more gradual, peaking at 5.8°C at 1 min 50 sec. then gradually decreasing at a slightly lower level than the temperature at PDJ. The temperature decreased in enamel and dentin when water was used as a coolant. The temperature drops initially at DEJ and PDJ where uniform. When preparation entered the dentin, there was a greater drop, with a sudden drop near the end of preparation whereas DEJ temperature increased after initial slight decrease.

**ANTHONYH.L.TJAN, BEN.E.GRAN (1989),** [7] evaluated the temperature rise in pulp chamber during fabrication of provisional crowns. The results suggested that the amount of heat transferred to the pulp chamber during polymerization of the resins might be sufficient to cause thermal damage to the dental pulp and odontoblasts. Curing provisional resin crowns in either addition or condensation silicone putty impressions significantly reduced the temperature rise in pulp chamber.

**WH RAAB et al (1989)** [56] studied the changes in the blood flow within the dental pulp and reported as a reaction to thermal stimuli between 17°C and 57°C. The blood flow changes were studied using Laser Doppler Flowmetry. The results indicated that the temperature below 31°C resulted in reduction and above 41°C resulted in an increase in blood flow. Furthermore, temperatures higher than 49°C caused irreversible damage to the pulpal microcirculation. The reduction in blood flow was attributed to the afferent rather than the sympathetic innervations of the tooth pulp as explained by using nerve blocks.

**H.CH.LAUER et al (1990)** [44] studied on effects of the temperature of cooling water during high-speed and ultrahigh-speed tooth preparation. The in vitro measurements of heat production in the pulp chamber during tooth preparation were performed on intact third molars. The experiments were designed to simulate physiologic temperature conditions in the tooth and oral cavity and to standardize parameters of tooth preparation. Two drive systems, the turbine and the high-speed angle, were compared by using two range of cooling, water temperature. The critical temperature of 41°C to 42°C that is irreversibly harmful to pulpal tissue was not reached with a cooling water temperature of 30°C to 34°C. Because the temperature elevation during turbine preparation was dependent on the diminishing thickness of remaining dentin, in preparing teeth close to the pulp, a high-speed angle was advantageous.

**TAIRA M, WAKASA .K (1990),** [67] studied on heat generated when cutting natural tooth enamel, composite resin model tooth enamel and ceramic typhodont tooth. He concluded that there was an increase in pulp temperature of about 15°C under 20g load and 20°C increase with 40g load without water as coolant. Also there was lesser than 1°C increase 45ml/min was used when water was used as coolant.

**GOODIS et al (1990), AND MATHEWS et al (1993),** [30,48] studied the air blast induced evaporative water loss from human dentin, in their in vivo experimental set up. According to this study blowing air on dentin induces very rapid outward fluid flow in dentinal tubules.

**HARROLD. E.GOODIS et al (1991)** [31] evaluated the histological pulp response to temperature probe placement in *Macaca fascicularis* monkey. First and second premolars and molars in three quadrants were used in this study. The fourth quadrant was used as control. An opening was made in the mesiobuccal line angle of 1mm above gingival crest to 1mm above gingival crest to DPJ. The probes were positioned in place with composite resin and MO cavity prepared in each tooth. Temperatures were recorded using a thermocouple and cavities sealed with cavit. The animal was sacrificed and specimens of each tooth were prepared and decalcified with 5% formic acid sodium citrate. Histological examination indicated inflammatory response in some section and was evident that RDT was less than 1mm. RDT greater than 1mm showed no response. Inflammatory response included an initial phase of dilatation and congestion of blood vessels with subsequent edema fluid, odontoblastic displacement into tubules.

**MARK E. VUKOVICH et al (1991)** [47] studied on heat generated by grinding during removal of ceramic brackets. When ceramic brackets fracture during treatment or at the time of debonding, it may become necessary to remove residual fragments by grinding with a hand piece. However, the grinding of ceramic surfaces may generate temperatures high enough to have detrimental effects on dental pulp. Intrapulpal temperature measurements were made on extracted teeth during bracket grinding with a small thermocouple probe fixed to the pulpal wall subjacent to the bracket position. These measurements were then compared with established threshold temperatures that have been reported to cause pulpal pathosis. They removed 122 ceramic brackets from eight extracted teeth by grinding with high speed diamond burs or low -speed green stones, with both with and without air or water coolant .It was determined that low- speed grinding without coolant resulted in significant ($p<0.001$) increase in pulp chamber temperature for all three types of brackets. Neither high speed nor low speed grinding during bracket removal caused a rise in temperature when combined with air or water coolant.

**P.D. LARFORGIA et al (1991)** [43] studied on temperature change in the pulp chamber during complete crown preparation. Twelve extracted, morphologically intact human teeth were chosen: four canines, four premolars, and four molars. Six teeth, two of each, were cooled during preparation with an air-water spray; the remaining six were air-cooled. Minimal reduction of dentin using an air-water spray coolant resulted in a lowered temperature in the pulp chamber, mainly with the cross-grooved TDA diamond stones. The application of an air coolant resulted in a temperature rise in the pulp chamber**.** The initial temperature of 37° C decreased for the air –water spray-cooled preparations with both types of diamond stones, but there was a greater decrease with the TDA diamond stones. The temperature changes revealed after first few minutes were an average decrease to 28.6 ° C with standard diamond stones and a decrease to 27.2°C with TDA diamond stones. After 2 minutes there was an average decrease to 27.7°C with the standard diamond stones and to 26.9°C with TDA diamond stones. While after 3 minutes average reduction to 26.9° C for standard and 24.8° C with TDA diamond stones. After 4 minutes, average decrease with diamond stones was 25.7°C and 25.1°C for TDA stones.

Conversely for air-cooled preparations the starting temperature of37°C increased with both standard diamond and TDA diamond. However, increase was slightly less for TDA diamond stones. After 2minutes there was an average increase to 43.2° C with standard stones and up to 41.6°C. Finally after 4 minutes there was an average increase to 40.6°C with standard and 37.7 °C with TDA diamond stones.

**D.H. PASHLEY (1991)** [53] studied on clinical correlations of dentin structure and function. Under most conditions the dentinal channels permit bi-directional diffusion of exogenous substances across dentin. Occasionally, hydrodynamic stimuli will produce transient, rapid movement of dentinal fluid that will induce pain. Many clinical problems such as poor dentin bonding, micro leakage, dentin sensitivity, and pulpal irritation have a common denominator in the structure and function of dentin.

**G.P STEWART et al (1991)** [65] studied the temperature rise produced by finishing of restorations utilizing 4 variables (viz., restorative material, finishing agent, finishing time and depth of dentin under restoration.). The results indicated that the amalgam produced highest temperature rise, while composite and ionomer were no different from untreated tooth. Aluminum oxide discs produced the least rise in temperature. Furthermore, temperature linearly increased with continuous finishing.

**I.ANIC et al in (1992)** [5] studied the temperature change in enamel tissue and the pulp chamber under the influence of a $CO_2$ laser at 0.5, 1.5, 2, 4, 6W and exposure times of 0.5, 10, 15, 20,30 seconds and a focal spot size of 1 and 1.5 mms. Temperature probe measurements with a digital thermometer, X-ray diffraction analysis and scanning electron microscopy was done to determine temperature change on surfaces. The results indicated rise of 3.5 and 4.1 °C with a 4W, 1mm focal spot size wave for 15 and 30 secs respectively. 11W, 1.5mm spot size wave for 10 and 20 seconds produced a temperature rise of 4.0 and8.0° C respectively after 30 seconds. SEM showed craters with needle shaped formations, which are attributed to micro explosions of vaporized steam or rapid cooling and solidification of the molten enamel after laser irradiation. Further more, concluding from temperature changes , powers of 1W up to 1 sec does not cause irreversible pulp tissue changes. Under in vivo conditions pulp-dentin complex would be subject to the greater thermal conductivity.

**KIM S, DOSCHER- KIM J, LIU M (1992),** [42] studied on functional alteration in pulpal microcirculation in response to various dental procedures and materials. Crown preparation with a high-speed bur without water spray has been shown to decrease blood flow in pulp of dog canines. Preparation to the same depth had negligible effect on the pulpal blood flow when abundant water spray was used to cool the bur. Dry preparation halfway into dentin resulted in a significant increase in blood flow through shunt vessels, especially those in the apical part of the teeth.

**ANDERSEN E, et al (1994),** [3] evaluated the effects on pulpal blood flow during cooling and heating of the human teeth. Laser Doppler Flowmetry (LDF) was used to study the changes in pulpal blood flow (PBF) evoked by application of cold or heat to the palatal surfaces of teeth 11 or 21 in nine young subjects. Switching from a thermode temperature of 33$^{o}$C to 5$^{o}$C on average induced a slow decreases of PBF to about 80% of control, and also warming to 39$^{o}$C evoked a small reduction in most subjects. Interindividual differences were large, however and both cooling and warming and sometimes triggered a rise in PBF. The results suggested a more complex interaction between local and neural mediated effects of moderate changes in temperature in the tooth pulp than skin, and that the previously held view of cold and heat decreasing and increasing PBF, respectively, is contradicted.

**BRIAN J.MILLAR et al (1995**) [14] studied on temperature increase during removal of incisal extensions on resin-bonded castings. The in vitro reduction of cast metal frameworks caused temperature elevation in dentin. This rise in temperature was greater when complete incisal locating extensions were removed, compared with narrower fingerlike extensions. Care should be exercised when "locating extensions" are ground with high-speed dental hand pieces. Thin fingerlike extensions are preferable to complete bulky incisal locating extensions.

**KIM .A. LAURELL et al (1995**) [41] studied on histopathologic effects if kinetic cavity preparation for the removal of enamel and dentin. Preparation of teeth in mixed-breed dogs with the use of the KCP technique causes the same or fewer pulpal changes than conventional high-speed rotary instrumentation with a copious water spray. Direct exposure of soft tissue in dogs to air abrasion caused no lasting adverse soft tissue effects.

**ANIL N. et al (1996)** [6] studied the temperature changes in the pulp chamber 1min after application of heat of 0, 40,60, 80°C to composite and amalgam cores and the period of time necessary for the temperature in the pulp chamber to return to36°C was one minute. The results showed that both for the amalgam and for the composite cores, the lowest increase in pulp temperature was established after 40° C heat application. Furthermore, higher temperature for a short duration might cause pulpal damage due to dissipation of heat by the tooth and inherent intrinsic moisture control of dentin. Prolonged periods of temperature raise cause inflammation and pulp death.

**HUNG et al (1996)** [37]studied the intra cellular calcium and extra cellular calcium required for response of bone cells experiencing fluid flow. According to them tear of the cell membrane induce calcium entry in to the cell possibly leading to cell death. A similar mechanism could damage the odontoblasts.

**PASHLEY (1996),** [54] studied the dynamics of the Pulpo dentin complex. Accordingly evaporative fluid flow is considered as additional cause of pulpal irritation.

**E.MIZRAHI et al (1996**) [49] studied the tooth surface at bracket tooth interface and pulp chamber temperature during electro -thermal bonding. Temperatures were recorded with 5 and 7.5A current applied as 1second time impulse with time intervals between pulses of 1,2,3,4 seconds. The results showed a rise of 43.3°C to 53.6°C with 5 A current and 77.5°C to

85.9°C with 7.5 A current. The pulp chamber temperature rise was evaluated for mandibular molars. The rise in temperature was 2.1° C (5A) and 2.8°C(7.5A) for mandibular incisors and 0.9to 1.6°C for premolars. The variation in temperature rise was attributed to the variable dentin thickness between sample teeth. On the basis of current evidence, increase in pulp chamber temperature during electro-thermal bonding may be considered to be clinically safe.

**OLAGART LM (1996),** [52] studied on the neurogenic components of pulp inflammation. He summarized the findings from a series of experiments on cats over a period of 25 years that included common clinical procedures using neurophysiologic and hemodynamic techniques. These procedures comprised grinding of dentin and percussion of the teeth. Brief grinding (1second, 3 times) of feline canines with a diamond bur flushed with saline at 6,000rpm caused an instantaneous increase in flow. The grinding halfway into dentin caused a 53% increase in blood flow lasting for about 10 minutes.

**CRAIG (1997),** [23] in his book on restorative materials has defined and compared thermal conductivity, specific heat and thermal diffusibility of various dental tissues and restorative materials.

**BALDISSARO .S. CATAPANI & R. SCOTTI (1997),** [8] studied clinical and histological evaluation of thermal injury thresholds in humans. Preliminary results suggest the average increase of 11.2°C do not damage the pulp since no signs of inflammation and no reparative processes, were suggested in the test samples within 68-91 days after the treatment. Results suggested that heat plays a secondary role in the generation of pulp pathologies during the postoperative period of dental treatment and prosthetic treatment in particular. The main etiological factor in pulp pathology could be dentin injury, which causes a considerable exposure of a tissue that is in direct physiological and functional continuity in the pulp. This factor could be compounded by possible cofactors such as bacterial intrusion, chemical irritation and osmosis.

**PETER OTTL et al (1998)** [55] studied on temperature response in pulpal chamber during ultra high - speed tooth preparation with diamond burs of different grit. The maximal temperature elevation within the pulp was 3.2°C, and the most pronounced rise in temperature occurred with ultra coarse burs. Temperature increases in the pulpal chambers and grinding times or temperatures of the cooling water approximately proportional, residual dentinal thickness was inversely proportional to temperature elevation within the pulpal chamber. This study demonstrated that coarse diamond burs resulted in more pronounced temperature increases within the pulpal chamber during tooth preparation. In addition, the benefit of short intervals between grinding steps and a cooling water temperature between 30°C and 32°C was confirmed. A cooling temperature of 38°C to 43°C did not afford actual cooling.

**CHRISTOPHER D.J. EVANS & PETER R. WILSON (1999)** [25] studied on the effects of tooth preparation on pressure measured in pulp chamber in laboratory set up. At 0 to 1 min of remaining dentin depth dry cutting with diamond and tungsten carbide burs generated a mean positive pulpal pressure of 12 kPa and 6 kPa, respectively. Wet cutting under the same conditions produced 0.6 kPa and 0.15 kPa, respectively. The difference between wet and dry cutting was highly significant ($P < 0.001$). Diamond burs produced significantly higher pressure increases than carbide burs at all levels for both wet and dry techniques ($P < 0.05$). When cutting farther than 2 mm form the pulp, tooth preparation created a mean 0.09 kPa pressure increase, which was not influenced by either coolant use or bur type. The temperature change was minimal during wet cutting and only minor temperature increases were recorded during dry cutting. From this laboratory study it is concluded that significant pressure changes occur in the pulp chamber during tooth preparation of extracted teeth when the remaining dentin thickness is less than 2 mm.

**B.E.KELLS et al (2000**) [39] studied on computerized infrared thermo graphic imaging and pulpal blood flow. Rewarming of healthy human teeth following a controlled cold stimulus. Three minutes is an appropriate time to record rewarming of teeth cooled for 20 seconds with an air stream at 20° C.

**T.F. WATSON et al (2000)** [69] studied on High and low torque hand pieces: cutting dynamics, enamel cracking and tooth temperature that when lightly loaded the two hand piece types performed similarly. However, marked differences in cutting mechanisms were noted when increased forces were applied to the hand pieces. No differences were recorded for temperature rise during cavity preparation. This study showed that the high torque hand pieces had better cutting pattern without any adverse effects. All the cavities prepared under water spray, irrespective of hand pieces speed to bur, decreased the mean temperature in pulp chamber from 37°C. When cavities were prepared dry the mean pulpal temperatures were 5°C higher than with a water spray, but there was still a net drop in tooth temperature. Although not a major component of the study, it is interesting to note the slight relative increase in temperature when using diamond burs as compared with a fluted tungsten carbide burs.

The mechanism for this may be attributable to the greater contact between the diamond grit and the enamel, hence raising frictional heat, compared with the blades of the tungsten burs. In this situation the flutes may allow a slight cooling action. A corollary of this is that the thickness of smeared layer has been reported to be a greater when diamond burs are used.

Differences in cutting mechanisms were seen between handpieces with high and low torque, especially when the loads and cutting rates were increased. The speed increasing handpiece was better able to cope with increased loading.

**SELZER (2000),** [59] in his book THE PULP suggested the pulpal reaction to various restorative procedures is not necessarily caused by excessive heat production.

**RW. LONEY AND RBT PRICE (2001)**, [46] studied on temperature transmission of high-output light-curing units through dentin. The conclusions of this study were thicker dentin specimens reduced temperature changes at the recording surface ($p<0.0001$). The plasma arc curing light, used for three seconds, produced lower mean temperature changes compared to the quartz tungsten halogen unit with either the standard or Turbo light guide. The Turbo Light Guide tip, when used for 40 seconds, increased the temperature rise by 42% to 56% when compared to the standard light guide on the same light for the same curing time, depending on dentin thickness.

**IVAR A.MJOR, (2001),** [38] studied pulp -dentin biology in restorative dentistry. Adequate cooling of a bur cutting at high speed is essential to prevent histological changes in the dentin and injury to the underlying odontoblastic region of the pulp. Temperature increases can cause severe injury to the pulp, and coolants should be always used in cavity and crown preparation. Intermittent cutting using light hand-piece pressure can minimize increase in temperatures during cavity and crown preparation. The injury inflicted on dentin and pulp when cooling of the bur is inadequate during cavity and crown preparation of dentin can lead to displacement of odontoblastic nuclei into dentinal tubules.

He also said that combination of dry preparation with high speed and use of anesthetic with vasoconstrictor are considered to be particularly harmful to the pulp. He said that provided adequate water spray is used during cavity preparation, displacement of nuclei will not occur. Evaporation of the contents of the tubules also occurs due to inadequate cooling of the bur or excessive drying of prepared surfaces. Capillary forces will then replace the lost dentinal fluid with the interstitial fluid in the pulp. He also found that increase in blood flow, as an immediate reaction to the grinding of dentin is likely to increase the tissue fluid pressure locally.

**C LIEU et al (2001)** [45] measured and compared peak temperature during polymerization of 5 provisional restoration resins. The materials were 2 self curing resins (protemp and integrity) and 3 dual cure resins(Iso-temp, TCB, ProvipointDC). The temperature rise of different resins was recoded every 10 seconds over 10 min period. The result showed higher increase in temperature with self-cure resins (33.8to 35.6°C). The reduction in temperature elevation with dual cure resins was attributed to the exothermic reaction occurring at different times- chemical followed by light curing.

**BRUNO N CAVALCANTI et al (2002)** [16] Studied on High-speed cavity preparation techniques with different water flows. The temperature increases with the high-load technique were 16.40°C without cooling (group I), 11.68°C with 30ml/min air-water spray cooling (group III), and 9.96°C with 45 ml/min cooling (group V). With the low-load tooth preparation technique, a 9.54°C increase resulted with no cooling (group II), a 1.56°C increase with 30 ml/min air-water spray cooling (group IV), and a 0.04°C decrease with 45 ml/min cooling (group VI). The low-load technique was associated with more ideal temperature changes. The results of this study confirm the necessity of using a low-load technique and water coolants during cavity and tooth preparation procedure.

**SHARON C. SIEGEL (2002)** [60] studied on the Effect of hand piece spray patterns on cutting efficiency. He studied that Cutting Rates (CR) varied by the type of cut and the number of spray ports. No differences were found in CRs for the three handpieces during edge cutting. The one-port hand piece cut significantly slower ($p<0.001$) than did the three and four port handpieces during groove cutting. The data indicate that the number of hand piece spray ports, and their positioning relative to the bur affect water supply to the cutting interface and, consequently, the CR under these study conditions.

**P.E.MURRAY et al (2003),** [50] studied on remaining dentine thickness and human pulp responses. The remaining dentine thickness (RDT) of the cavity mediates a powerful influence on underlying pulp tissue vitality but it has little effect on reactionary dentine secretion and inflammatory activity. Gross tissue injury, explain the poor pulp capping prognosis following exposure and underlies the need to avoid this type of injury. Following restorations, a RDT of 0.5 mm or greater is necessary to avoid evidence of pulp injury.

**BRUNO N CAVALCANTI et al (2003)** [17] studied the temperature increase produced by high speed dental handpieces with those produced by Er:YAG laser. 30 bovine mandibular incisors were selected and Class V preparations were completed to a depth of 2mm. Preparations were performed using high speed hand piece without water cooling, with water cooling, and Er: YAG non contact with water cooling. Temperature rise was measured using thermocouple. Temperature increases of 11.64±4.35°C and 0.96± 0.71°C was observed for non cooled and water-cooled hand piece preparations. The Er: YAG laser had an average temperature rise of 2.69 ±1.12 °C. The effects of water coolant were shown to be statistically significant. The water flow modifies the rate of ablation of dental tissues and a water flow rate of 4.5ml /min is adequate to control temperature and maintain ablation capacity.

**GHOLAMREZA DANESH et al (2004)** [28] studied on temperature rise in the pulp chamber induced by a conventional halogen light-curing source and a plasma arc lamp. The lowest temperature increase (0.3 C) was recorded during composite polymerization with a previously applied cement base using the Apollo 95E unit (Group C, P<0.05). The highest temperature increase was induced when using the Elipar Visio unit directly over the untreated cavity (Group A, P<0.05). In Groups A, C and D higher pulp chamber temperature measurements were using the Elipar Visio unit as compared to the Apollo 95 E plasma are lamp 9p<0.01). in Group B, no significant differences were recorded during the composite polymerization when using the two different light-curing units. Compared to a conventional halogen curing lamp, the high-speed curing of resin-based composite using the high-energy plasma are lamp Apollo 95E for 3 seconds did not increase the temperature in the pulp chamber.

**BRUNO NEVES CAVALCANTI, et al (2005)** [18] studied on water flow in high-speed handpieces that the average water flow for 137 samples was 29.48 ml/min. The flow speeds obtained were 42.38 ml/min for turbines with one coolant aperture; 34.31 ml/min for turbines with two coolant apertures; and 30.44 ml/min for turbines with three coolant apertures. There were statistical differences between turbines with one and three coolant apertures (Turkey-Kramer multiple comparisons test with P < .05). Turbine handpieces with one cooling aperture distributed more water for the burs than high-speed handpieces with more than one aperture.

**TANCAN UYSAL et al (2005),** [68] studied on thermal changes in the pulp chamber during different adhesive clean up procedures .The study was to measure the temperature changes in the pulpal chamber when different adhesive clean up procedures were used. Ninety intact extracted human maxillary incisors were used in the study. The teeth were divided into six groups of 15 teeth each .The removal of remaining composite on the tooth surface was performed with a tungsten carbide bur. The residual adhesive was removed using a high-speed hand piece with or without water-cooling and a contra- angle hand piece with or without water-cooling at high and low speeds. A J-type thermocouple wire was positioned in the center of the pulp chamber .The result was analyzed with analysis of variance decrease (ANOVA) and the turkey honestly significant difference test. Two –factor ANOVA revealed significant interaction between the hand piece type and water cooling .In this study, the high speed contra–angle handpieces without water cooling group had the highest $\Delta T$ values (7.58°C±1.84°C) among all the clean up procedures. The decrease in pulpal temperature with water-cooling was –5.34°C for the hand piece, –5.36°C for the low speed contra angle hand piece and -4.98° high-speed contra angle hand pieces.

**M.SULIEMAN et al (2005),** [66] studied on surface and intra-pulpal temperature rises during tooth bleaching (in vitro). The increase in surface temperature readings ranged form 0.44$^{o}$C (luma arch) to 86.3$^{o}$C (laser) with no bleaching gel present intra-pulpal temperature increases ranged from 0.30$^{o}$C to 15.96$^{o}$C. The presence of the bleaching gel reduced temperature increases seen at the tooth surface and within the pulp. The increase in the intra-pulpal temperature with most bleaching lamps was below critical threshold of a 5.50$^{o}$C increase thought to produce irreversible pulpal damage. The only lamp that produced an intrapulpal temperature increase above this threshold was the laser-based lamp and caution is advised when using this equipment.

**ABHISHEK SINGH et al (2005),** [1] studied on in vitro pulp chamber temperature rise during composite resin polymerizations with different curing lights. The plasma arc curing light produced the maximum temperature rise during composite resin polymerization, followed by the Halogen-Tungsten lights and LED Lights. Remaining Dentin thickness (RDT) was inversely related to the temperature rise during resin polymerization. Based on the composite resins used for different situations in this study, the LED curing light was evaluated as comparatively SAFE.

The use of a cement base is recommended in deep cavities for pulp protection during restoration with light cured composite resins.

**C.W.BARCLAY et al (2005),** [9] studied on intra-oral temperatures during function. This study assessed the range of temperatures that selected group could tolerate when drinking and also assessed the range of temperatures encountered in various intra-oral sites. Miniature data loggers allowed for accurate measurements and recording of temperature form selected sites. The maximum and minimum mouth temperatures recorded show that hot fluids can raise the intra-oral temperature of the anterior teeth to around $70^{o}$C and the consumption of iced drinks lowers the same teeth to around $0^{o}$C.

**J.C. BUDD et al (2005)** [20] studied on temperature of the post and on the root surface during ultrasonic post removal. The overall mean pooled effect showed that temperature rise for P=20.1 ± 27.9° C and R=10.9 ± 7.9° C were significantly different. There were significant difference in temperature rise as a function of ultrasonic device, location on the tooth and cooling method utilized for post removal. .

# MATERIALS AND METHODS

The aim of this in – vivo study was to measure the temperature variation observed in the pulp chamber during tooth preparation with and without the use of aqua coolant and compare the advantage over temperature control offered by aqua coolant during every stage of tooth preparation.

The entire study consisted of following divisions;

1) Case selection and informed consent.
2) Selection of tooth.
3) Access channel preparation.
4) Initial pulpal temperature determination with thermocouple.
5) Assessment of pulpal temperature variation during tooth preparation in the presence of aqua coolant.
6) Assessment of pulpal temperature variation during tooth preparation in the absence of aqua coolant.

**Equipments:**

1) THERMOCOUPLE (UV-Chennai): It was used to estimate the intrapulpal temperature during tooth preparation. It consisted of a K type chromel - alumel components, which measured the temperature variation. The thermocouple wire was 0.5mm in cross sectional diameter. This wire

was insulated to the full length except for the tip, which acts as a sensor for measuring temperature and was connected to a digital temperature indicator (C1E 305)( pic- 2).

Principle Of Thermocouple: The temperature variation that was produced was estimated by a K type thermocouple with a positive nickel-chromium arm and negative nickel-aluminium arm. Any variation in temperature between the junctions of two alloys generated a voltage that was proportional to temperature elevation. This is known as the Seebeck effect.

2) DIGITAL TEMPERATURE INDICATOR (DTI) (C1E 305). A standardized, certified, battery operated digital temperature indicator, which is calibrated to record temperatures in the range of - 500°C to +500°C was used. The DTI also had the provision for display of temperature in Fahrenheit scale and it possessed the precision to record very subtle changes up to a difference of 0.1°C or F. Accuracy of DTI was checked by simultaneous assessment of intra oral temperature with digital thermometer and subsequently with analog thermometer. The digital indicator also had an offset adjustment for zeroing of the instrument at any temperature.

3) RADIOVISIOGRAPHIC UNIT: (New Life radiology – Italy) X-ray unit of 70 Kvp and Planmeca Dimaxis assembly for RVG was used to verify thermocouple position intrapulpally.( pic-3,4)

4) ANALOG THERMOMETER:TIP–TOP -DPR Korea. It is a mercury thermometer to record body temperature.

5) AIR TURBINE: Ultra high speed, high torque air turbine (Pana air-T NSK JAPAN) with a non-contact RPM of 3.5 lakh was attached to dental chair unit which was used for tooth preparation. Pressure in the dental unit was maintained between 30-40 psi. (pic-5)

6) LIGHT CURE UNIT: Light emitting diode (LED) polymerization unit (Blue phase C5 , IVOCLAR VIVADENT) was used for curing composite bonding system.

**Materials:**

1. BURS (pic-5): DIAMOND

**A)** BR41 Mani: Round bur of 2mm diameter was used to prepare a pilot channel on enamel

**B)** FO32 Mani: Flame shaped bur was used for occlusal preparation.

**C)** TR13 Mani: Radial shoulder bur was used for groove , labial and lingual preparation.

**D)** TR21EF Mani: For finishing of various surfaces.

TUNGSTEN CARBIDE:

**E)** SSWFG4 SS White: Round TC bur for entering pulp through dentin via enamel access channel.

**2)** Bonding agent: Light cured, self-etching self-priming bonding agent (XENO-Densply) was used to initially stabilize thermocouple wire in the pulp chamber. ( pic-6)

**3)** Composite: Self-curing composite (Rely-A-BOND, USA), which consist of primer and paste, was used to pack gap between wire and pulpal access channel on tooth thus discommunicating the pulpal chamber from external environment.(pic-7).

**4)** Applicator brush (Micro brush): For bonding agent and primer application.

**5)** Lignocaine (LIGNOX): 2% lignocaine with 1in 200000 adrenalin was used to anaesthetize tooth with aid of 2ml syringe and 26-gauge needle.

## **Accessory Armamentarium** (pic-1)

**1)** Mouth mirror

**2)** Explorer

**3)** Tweezers

**4)** Plastic instrument

**5)** Cotton holder and cotton

**6)** Scissors, Gauze

**7)** Suction tip

**8)** Dappen Dish

9) Spirit

10) Autoclave

11) 2% glutaraldehyde

12) Disposable mask, gloves

13) Patient apron

14) Cheek retractor

15) Mixing pad

16) Cutting pliers

## STEP BY STEP METHODOLOGY:

- **Case selection and patient consent.**

Twenty, healthy, non-carious, vital, maxillary or mandibular premolars indicated for extraction for orthodontic therapy was chosen from different patients of age group of 14 - 30 yrs. The patients were explained ardently about the study and they were provided with a patient information sheet on which their informed consent was obtained.

- **Anaesthetizing the tooth:**

  Patient was comfortably seated on the dental operatory unit( pic-8). Intraoral temperature was recorded using the digital thermometer with a thermocouple and its values were verified using mercury analog thermometer(pic-9,10,11). The tooth chosen for intra pulpal temperature assessment was anaesthetized with 2% Xylocaine having 1 in 2,00,000 adrenalin.

- **Preparation of Access channel:** Using Super Torque Hand piece (NSK Japan) with an aqua coolant (30 - 34°C) at standard room temperature (28-34°C) operating at the chair pressure adjusted to 30-40 psi. With a round diamond (BR 41 Mani) an access channel was prepared through the enamel at cervical level on the palatal surface of the maxillary premolar or buccal surface of mandibular premolar (pic-12,13). This was followed by penetration in to dentin using TC round bur (SSWFG-4) until a dip into the pulp chamber was felt (14,15) Then the thermocouple wire was introduced into the pulp chamber(pic-16,17,18). The position of the thermocouple was verified radio graphically using a RVG (Dimaxis)(pic-19,20). The thermocouple was stabilized with the help of light cured self-etching self-bonding primer (Xenon Densply)(pic.21) and self cure composite (Rely-a-bond, USA)(pic-22). Patient was asked to close his mouth for 3 minutes and the intra pulpal temperature was recorded[39,22](pic-23)

- **Estimation of temperature alteration with tooth preparation:(**pic 24,25,26)

The tooth chosen for evaluation of intrapulpal temperature variation was examined carefully for any discontinuity at the site where thermocouple was embedded.

Initially the subjected tooth was exposed to non-contact run of turbine with or without aqua coolant for ten seconds and the change in temperature was recorded[70]. This was followed by sequential intermittent tooth preparation. The sequence was as follows:

(a) Placement of depth orientation grooves on occlusal surface using TR13 diamond.

(b) Occlusal preparation with FO32

(c) Placement of depth orientation grooves on labial surface of maxillary premolar and lingual surface of mandibular premolar with TR13.

(d) Labial preparation of maxillary premolar and lingual preparation of mandibular premolar with TR13.

(e) Finishing with finishing bur using TR21EF

Temperature variation during each procedure was recorded. When tooth was prepared without aqua coolant the highest temperature reached was recorded for each sequence. However when aqua coolant was used, the recording was made at the termination of each preparation[70]. For every tooth preparation new set of burs were used.

The subjects chosen for the study were arranged on two groups:

Group - I - Tooth Preparation with aqua coolant delivered at rate of 30 ml/minute

Group - II - Tooth preparation without aqua coolant

**Group - I**

Tooth Preparation with aqua coolant delivered at rate of 30 ml/minute.

The anaesthetized tooth with thermocouple in position was inducted for tooth preparation. Depth orientation bur was attached to the hand piece and the tooth was exposed to the running hand piece without bur contact for 10 seconds. The drop in temperature at end of 10 seconds was noted.

**(a) Occlusal Preparation:**

Depth orientation grooves were placed on the occlusal aspect. The change in temperatures at the end of groove preparation was recorded. This was followed by occlusal preparation using flame shape diamond (FO32). Temperature at the end of occlusal preparation was again recorded.

**(b) Labial/lingual Preparation:**

Depth orientation grooves were placed using TR13 bur on the labial aspect of maxillary premolar and lingual surface of mandibular premolar. The drop in temperature at the end of groove preparation was recorded. Followed by this, preparation using TR13 bur was done on labial surface of maxillary premolar and lingual surface of mandibular premolar. Respective temperatures at the end of preparation were recorded.

**(c) Finishing Procedure:**

Using TR21EF bur, occlusal, labial and lingual preparations were finished and their respective temperature were recorded. At the end of procedure the thermocouple was removed and tooth was sent for extraction.

## Group - II

Tooth preparation without aqua coolant

The anaesthetized tooth with thermocouple in position was inducted for tooth preparation. Depth orientation bur was attached to the hand piece and the tooth was exposed to the running hand piece without bur contact for 10 seconds. The drop in temperature at end of 10 seconds was noted.

**a.Occlusal Preparation:**

Depth orientation grooves were placed on the occlusal aspect of the chosen tooth. The change in temperatures was recorded. This was followed by occlusal preparation using flame shape diamond

(FO32). Maximum temperature during occlusal preparation was again recorded.

**(b) Labial/lingual Preparation:**

Depth orientation grooves were placed using TR13 bur on the labial aspect of maxillary premolar and lingual surface of mandibular premolar. The maximum change in temperature was recorded. Followed by this preparation using TR13 bur was done on labial surface of maxillary premolar and lingual surface of mandibular premolar. Respective maximum change in temperature was recorded.

**(c) Finishing Procedure:**

Using TR21EF bur, occlusal, labial and lingual preparations were finished and their respective maximal temperature were recorded. At the end of procedure the thermocouple was removed and tooth was sent for extraction.

The values were recorded for all the subjects in similar manner and were tabulated with integral calibration as variation from initial temperature. The subjects were arranged into two groups; preparation with aqua coolant (α group) and preparation without aqua coolant (β group). The preparations were sub grouped into groove preparation (GP) i.e. (αGP,βGP), surface preparation (SP) i.e. (αSP,βSP) and finishing preparation (FP) i.e. (αFP,βFP), with each sub group having two divisions occlusal preparation (O) i.e.(αGPO,αSPO,αFPO & βGBO,βSPO,βFPO) and labial / lingual preparation(L) i.e. (αGPL,αSPL,αFPL & βGPL,βSPL,βFPL).This was done because during groove preparation rotating bur will be in contact bilaterally with the tooth. Thus increase in the area of bur tooth contact generates additional frictional heat. During surface preparation only single side or plane of bur will contact the tooth, this type of preparation is also referred as edge preparation[60]. Values were tabulated and statistically analyzed.

# ***INVESTIGATION DESIGN***

**20 INTACT PREMOLARS SELECTED**

**PATIENT INFORMED AND CONSENT OBTAINED**

**INTRAORAL TEMPERATURE RECORDED WITH DIGITAL AND ANALOG THERMOMETER**

**LA GIVEN AND ACCESS HOLE PREPARATION DONE**

**THERMOCOUPLE WIRE INTRODUCED INTRAPULPALLY AND STABILIZED**

**RADIOGRAPHICALLY VERIFY THE POSITION**

| | |
|---|---|
| **TOOTH PREPARATION WITH WATER** | **TOOTH PREPARATION WITHOUT WATER** |

**RECORD TEMPERATURES**

**EXTRACT TOOTH**

**STATISTICAL ANALYSIS**

# RESULTS AND TABULATIONS

The subjects were arranged into two groups; preparation with aqua coolant (α group) and preparation without aqua coolant (β group). The preparations were sub grouped into groove preparation (GP) i.e. (αGP,βGP), surface preparation (SP) i.e. (αSP,βSP) and finishing preparation (FP) i.e. (αFP,βFP), with each sub group having two divisions occlusal preparation (O) i.e.(αGPO,αSPO,αFPO & βGBO,βSPO,βFPO) and labial / lingual preparation(L) i.e. ( αGPL,αSPL,αFPL & βGPL,βSPL,βFPL).This was done because during groove preparation rotating bur will be in contact bilaterally with the tooth. Thus increase in the area of bur tooth contact generates additional frictional heat. During surface preparation only single side or plane of bur will contact the tooth, this type of preparation is also referred as edge preparation. Finishing preparation was done with extra fine finishing bur requiring minimal feather touch preparation.

| S.NO. | NOTATION | EXPANSION |
|---|---|---|
| 1. | $\alpha$ | Preparation With water |
| 2. | $\beta$ | Preparation Without water |
| 3. | L | Labial / lingual preparation. |
| 4 | O | Occlusal preparation |
| 5. | GP | Groove Type preparation |
| 6. | SP | Surface Type preparation |
| 7. | FP | Finishing Type preparation |
| 8. | IO | Intra Oral Temperature. |
| 9. | IP | Intra Pulpal Temperature |

TABLE--I

MEAN INTRAORAL AND INTRAPULPAL TEMPERATURE.

| | No. Of samples. | Mean (°F) | S.D |
|---|---|---|---|
| IO | 20 | 98.71 | 0.3 |
| IP | 20 | 96.77 | 1.19 |
| DIFF | 20 | 1.94 | 1.23 |

PAIRED T-Test showed P Value $< 0.001$ which is highly significant.

In table I the mean value of IP temperature (96.77°F±1.39) is lower than the mean value of IO temperature (98.71°F±0.3) with a difference of 1.94°F ± 1.23, which is statically significant.

TABLE –II

TEMPERATURE VARIATION IN NON-CONTACT RUN

T-TEST FOR INDEPENDENT SAMPLES

| Group | No. Of samples | MEAN °F | S.D. | DIFFERENCE °F | P VALUE |
|---|---|---|---|---|---|
| α | 10 | - 4.57 | 0.57 | 0.2 | 0.733 Insignificant |
| β | 10 | - 4.77 | 0.57 | | |

In table II mean temperatures of α group (- 4.57±0.57) is less negative than mean temperatures of β group (-4.77± 0.57) with a difference of 0.2. However the result of T-test for independent samples show P value is 0.733. Hence the difference is insignificant.

TABLE --III

INTRA PULPAL TEMPERATURE CHANGE DURING EACH STAGE OF TOOTH PREPARATION

T-TEST FOR INDEPENDENT SAMPLES.

| Group / Type of prep. | α | | β | | DIFFERENCE °F | 2-Tail Sig (P-value) T-test |
|---|---|---|---|---|---|---|
| | MEAN °F | SD | MEAN °F | SD | | |
| GPO | - 5.38 | 1.15 | 2.78 | 2.02 | 8.16 | < 0.01 |
| GPL | - 7.85 | 1.52 | - 2.39 | 1.53 | 5.46 | < 0.01 |
| SPO | - 6.59 | 1.06 | - 2.68 | 1.95 | 3.91 | < 0.01 |
| SPL | - 8.13 | 1.49 | - 3.15 | 1.71 | 4.98 | < 0.01 |
| FPO | - 8.96 | 0.92 | - 4.29 | 1.80 | 4.67 | < 0.01 |
| FPL | - 9.39 | 0.934 | - 5.39 | 1.74 | 4.00 | < 0.01 |

In table III mean temperature variation of α group i.e α GPO(-5.38°F±1.15) αGPL (-7.85°F± 1.52), αSPO ( -6.59°F±1.06), αSPL (-8.13°F±1.49), αFPO ( -8.96°F±0.92), αFPL ( -9.39°F± 0.934) as compare to β group were β GPO (2.78°F±2.02), β GPL(-2.39°F±1.53), β SPO (-2.68°F±1.95), β SPL (3.15°F±1.71), βFPO (-4.29°F±1.80), βFPL (-5.39°F±1.74) are tabled. The difference between α and β for GPO (8.16), GPL (5.46), SPO (3.91), SPL (4.98), FPO (4.67), FPL (4.00), were subjected to T-test and the P value was <0.01 which is highly significant.

TABLE –IV

INTRA PULPAL TEMPERATURE CHANGE DURING EACH TYPE OF TOOTH PREPARATION

T-TEST FOR INDEPENDENT SAMPLES.

| Group / Type of prep. | α | | β | | DIFFERENCE °F | 2-Tail Sig (P-value) T-test |
|---|---|---|---|---|---|---|
| | MEAN °F | SD | MEAN °F | SD | | |
| GP | - 6.62 | 0.87 | 0.20 | 1.48 | 6.81 | < 0.01 |
| SP | - 7.36 | 1.10 | - 2.92 | 1.59 | 4.44 | < 0.01 |
| FP | - 9.18 | 0.921 | - 4.84 | 1.75 | 4.34 | < 0.01 |

In table IV mean temperature of α GP (-6.62°F±0.20), α SP (-7.36°F±1.10), αFP (-9.18°F±0.921), compared to β GP (0.20°F±1.48), βSP (-2.92°F±1.59), βFP (-4.84°F±1.75) is tabulated. T-test was done to find if there is significant difference between the 2 groups. The differences of GP (6.81°F), SP (4.44°F), FP (4.34°F) were found to be highly significant as P value was less than 0.01.

TABLE –V

INTRA PULPAL TEMPERATURE VARIATION WITHIN EACH GROUP OF PREPARATION.

T-TEST FOR PAIRED SAMPLES

| SUB GROUP DIFF. / GROUP | GP-SP | | | SP-FP | | | GP-FP | | |
|---|---|---|---|---|---|---|---|---|---|
| | MEAN °F | SD | P VALUE | MEAN °F | SD | P VALUE | MEAN °F | SD | P VALUE |
| α | 0.75 | 0.40 | < 0.01 | 1.82 | 0.73 | < 0.01 | 2.56 | 0.60 | < 0.01 |
| β | 3.11 | 1.08 | < 0.01 | 1.93 | 0.94 | < 0.01 | 5.04 | 1.82 | < 0.01 |

`In table V mean difference in temperature variation during various type of preparation within the same group were evaluated. Paired T-test was done. The values were as follows: mean α(GP-SP)=0.75±0.40, α(SP-FP)=1.82°F±0.73, α(GP-FP)=2.56°F±0.60, β (GP-SP)=3.11°F±1.08, β(SP-FP)=1.93°F±0.94, β(GP-FP)=5.04°F±1.82. The values were highly significant as P value was less than 0.001.

TABLE –VI

CORRELATION COEFFICIENT –WITH WATER

| TYPE OF PREPARATION | GP | SP | FP |
|---|---|---|---|
| GP | 1.000 | | |
| SP | 0.94 | 1.000 | |
| FP | 0.78 | 0.75 | 1.000 |

The table VI shows correlation between GP, SP, and FP in the α group. They showed positive correlation i.e. correlation between GP-SP was 94%, GP-FP was 78%, and FP-SP was 75%.

TABLE -- VII

CORRELATION COEFFICIENT –WITH OUT WATER

| TYPE OF PREPARATION | GP | SP | FP |
|---|---|---|---|
| GP | 1.000 | | |
| SP | 0.75 | 1.000 | |
| FP | 0.37 | 0.84 | 1.000 |

The table VII shows correlation between GP, SP, and FP within the β group. They showed positive correlation i.e. correlation between GP-SP was 75%, SP-FP was 84%, and GP-FP was 37%.

TABLE – VIII

FRIEDMANN TWO WAY ANOVA- WITH WATER

| S.NO | VARIABLE | MEAN RANK |
|---|---|---|
| 1. | GP | 3.0 |
| 2. | SP | 2.0 |
| 3. | FP | 1.0 |

| CASES | CHI SQUARE | DF | SIGNIFICANCE |
|---|---|---|---|
| 10 | 20 | 2 | < 0.01 |

TABLE --IX

FRIEDMANN TWO WAY ANOVA WITHOUT WATER

| S.NO | VARIABLE | MEAN RANK |
|---|---|---|
| 1. | GP | 3.0 |
| 2. | SP | 2.0 |
| 3. | FP | 1.0 |

| CASES | CHI SQUARE | DF | SIGNIFICANCE |
|---|---|---|---|
| 10 | 20 | 2 | < 0.01 |

Table VIII and IX shows the results of the Friedman 2-way ANOVA test. There is significant difference in the rank of all 3-sub groups.

TABLE -- X

TEMPERATURE VARIATION IN OVERALL TOOTH PREPARATION

T-TEST FOR INDEPENDENT SAMPLES

| Group | No. of samples | MEAN | S.D. | DIFFERENCE | P VALUE |
|---|---|---|---|---|---|
| α | 10 | - 7.27 | 0.87 | 4.4257 | < 0.01 Significant |
| β | 10 | - 2.8 | 1.3 | | |

TABLE – X I

MANN-WHITNEY U- WILCOXON RANK SUM W TEST

| Rank | Cases | |
|---|---|---|
| 5.50 | 10 WATER | 1 WITH WATER |
| 15.50 | 20 WATER | 2 WITHOUT WATER |

| EXACT | | | CORRECTED FOR TIES | |
|---|---|---|---|---|
| U | W | 2-TAILED P | Z | 2-TAILED P |
| 0.0 | 55.0 | 0.000 | - 3.7796 | 0.0002 |

Table XII

KOLMOGOROV- SMIRNOV 2 SAMPLE TEST

| | |
|---|---|
| 10 WATER | 1 WATER |
| 20 WATER | 2 WATER |
| 20 TOTAL | |

MOST EXTREME DIFFERENCES

| Absolute | Positive | Negative | K-S-Z | 2-Tailed P |
|---|---|---|---|---|
| 1.00000 | 1.0000 | 0.000 | 2.236 | 0.000 |

TABLE-XIII

WALD-WOLFOWITZ RUNS TEST

| | |
|---|---|
| 10 WATER | 1 WATER |
| 20 WATER | 2 WATER |
| 20 TOTAL | |

| | Runs | Z | Exact 1-Tailed P |
|---|---|---|---|
| Exact number of runs | 2 | -3.9055 | 0.000 |

Table X shows the temperature variation in overall tooth preparation within $\alpha$ and $\beta$ group. The difference between the $\alpha$ and $\beta$ group was 4.4257°F which was highly significant as per table X, XI, XII and XIII.

# DISCUSSION

The contemporary art and science of fixed partial prosthodontics summons sacrifice of intact tooth structures, enforcing an irreparable damage to the enamel and partially reversible partial recovery of pulp-dentinal complex. However 9.1% to 15% of teeth, which underwent crown preparation, exhibited signs and symptoms of loss of vitality as reported by Voss (1979) [40] and Bergenholtz (1983) [33], thus invoking an extensive investigation to establish the identity of the causal factor that instigated non-vital transformation of healthy pulp.

Two major factors viz. thermal and mechanical trauma were strongly associated in the plot against pulpal integrity. In terms of thermal tolerance threshold of the pulp Zach and Cohen (1965) [71] reported that a temperature raise of 5.5°C to be critical limit of the pulpal thermal tolerance. Baldissara suggested, up to 11.2°C [8] did not produce any irreversible pulpal damage and Pohto found 41.8°C [61] to be the critical limit for pulpal fibroblast and further many studies have been experimented to evaluate the thermogenesis during tooth preparation, cavity preparation and other dental procedures.

There have been numerous studies designed to evaluate variation in temperature during the tooth preparation in the presence and absence of water, the aqua coolant. The results of these studies have documented conflicting inferences of elevation and depression of pulpal temperature in various segmented samples.[11, 16,29,36,43,44,45,67,69,70.]

Hence this in vivo study was designed to estimate the amount of temperature advantage aqua coolant provides at every stage of tooth preparation and also evaluate pulpal temperature variation during tooth preparation in the presence and absence of aqua coolant.

Twenty healthy vital teeth (maxillary /mandibular premolars) of similar dimensions indicated for orthodontic extraction were chosen for the study. Subjects distributed within age group of 14-28 yrs were chosen to avoid incomplete apex formation below 14 yrs and above 28yrs teeth may undergo regressive alteration in form of attrition or abrasion. Subject consent was obtained for participation in the study.

A k-type thermocouple that was connected to battery operated digital temperature indicator was used in this study similar to other oral and dental temperature assessment studies. Individual new thermocouple wires were used to record temperature as thermocouple tip was in direct communion with blood. The clinical efficacy of the thermocouple was crosschecked by simultaneous assessment of intra oral temperature with analog thermometer.

An ultrahigh-speed high torque hand piece was used as it has high cutting rate (CR) and cutting efficiency [69]. The pulp was entered from the palatal surface of maxillary premolar and buccal surface of mandibular premolar with the use of TC bur as studies have shown that TC bur has reduced thermogenesis (Watson 2000) [69]. Thermocouple wire was introduced into the pulp and stabilized. A similar methodology was used by Zach and Cohen[70, 71] for his studies and also by Goodies et al [31] (1991).The position of thermocouple tip in to the pulp chamber was verified using RVG as it is a highly precise radiographic technique with added advantage of lesser processing time and exposure time. The stabilization of thermocouple was done initially using self-etching self-priming bonding agent (XENO-Densply) to avoid alteration in temperature due to rinsing of the etchant. Further it was stabilized with self-curing composite (Rely-A-Bond, USA) to isolate the thermocouple tip with pulp from the external environment.

Subjects were asked to close the mouth for 3minutes as per the average rewarming of pulp when exposed to cold stimulus given by KELLS (2000) [39]. In each experimental run the temperature was recorded prior to the preparation procedure. This reading was henceforth was regarded as initial temperature. After recording temperature tooth was exposed to non-contact run for 10 seconds either with or without coolant.

This modification from actual clinical technique was adopted for the following reasons:

1. Coolant conditions during the time the operators hand approached the tooth were standardized.

2. Interval of 10 seconds allowed equilibrium to be established between coolant effect and pulpal circulation.

3. By starting to drill only after the coolant had taken full effect, the pattern of thermal changes caused by drilling was made clearer.

The heating trend was thus isolated from the rapid cooling trend of the coolant [70]. The bur contact with the tooth was intermittent throughout the preparation. Temperature of aqua coolant (water) was maintained between 30-34°C as this temperature causes pulpal cooling as given by LAUER (1990) [44] and rate of flow of water was adjusted to be 30ml/min as per observation by BROUNO (2000) [18]. The operatory room temperature fluctuated around 28 to 34°C.

When tooth was prepared without water coolant the highest temperature reached is recorded for each sequence of tooth preparation. The temperature continues to rise in some cases after preparation is terminated; no time limit was imposed. However when aqua coolant was used the recording was made at the termination of each preparation. Water that remained on the tooth caused the temperature to drop below that was recorded during preparation procedure [70]. New sets of burs were used every time to ensure maximum cutting efficiency of bur.

Interpretation of results:

The average intrapulpal and intra-oral temperature was found to be 96.77°F and 98.71°F. Intrapulpal temperature was found to be 1.9450°F lesser than intra oral temperature (table I). Similar observations were mentioned by Funakoshi (1963) [27] and Scott (1965) [58].

The drop in intrapulpal temperature during tooth preparation by non-contact bur with aqua coolant was by 4.57°F and without aqua coolant was 4.77°F. Even though, there was difference of 0.2°F it was statically insignificant. However, the drop in temperature without water was surprisingly more rapid. When no water is used, the exhaust air from the air turbine acts as coolant. This exhaust air produces whirl or turbulence around the rotating bur, which acts on entire surface of tooth (Schuchard 1965)[57]. A possible explanation for additional drop lies in the evaporative effect of the air over the moist teeth (Cohen 1962).[70]

When comparing occlusal groove with and without aqua coolant, aqua coolant caused 8.16°F more cooling than preparation without coolant and the value was statistically significant. Similarly, when comparing other preparations it was found that aqua coolant caused 3.91°F more cooling than during occlusal preparation, 5.46°F more cooling than during labial groove preparation, 4.98°F more cooling during labial preparation, 4.6°F more cooling during occlusal finishing and 4°F during labial finishing than without the use of aqua coolant (table III). During labial / lingual preparation exhaust air from handpiece flowed over prepared occlusal surface, as would occur in clinical situation where occlusal surface is prepared prior to labial / lingual preparation.

When comparing preparation with or without coolant, it was observed that the coolant produced additional 6.81°F cooling during groove preparation, 4.44°F more cooling during surface preparation, 4.33°F more cooling during finishing preparation. This analysis revealed that difference in cooling effect due to water was most evident during occlusal groove preparation (table IV).

When water was used as coolant it was observed surface preparation caused 0.75 °F more temperature drop as compared to groove preparation and finishing preparation caused 1.82°F more drop in temperature as compared to surface preparation. When no water coolant was used it was observed surface preparation caused 3.11°F more drop in temperature as compared to groove preparation and finishing preparation caused 1.93°F more drop in temperature when compared to surface preparation. The results of this tests show that the use of coolant had most significant influence on temperature control during groove type preparation (table V).

Correlation coefficient test revealed there is positive correlation between groove, surface and finishing preparation i.e. temperature of groove type preparation influences the temperature of surface type preparation by 94.4% with use of water and 75.5% without use of coolant. Similarly, temperature of surface preparation influences the temperature of finishing type preparation 75.2% with use of water and 85% without use of water. The results of this test confirmed the use of aqua coolant to be more influential on temperature during groove preparation (table VI & VII).

Friedman two-way ANOVA test revealed that there is significant difference between mean ranks toward groove, surface and finish preparation of pulpal temperature with and without aqua coolant. The results of this test revealed that groove preparation had the most significant influence on thermogenesis (table VIII & IX). All these tests suggest that groove preparation is most significant in determining thermogenesis during preparation and use of aqua coolant has more temperature drop during groove preparation than surface and finishing preparation.

When comparing the overall tooth preparation with and without aqua coolant, it was found that use of aqua coolant caused 4.4257°F more cooling of the tooth when preparing than without coolant. These values were designated to be highly significant as per T-test for equality of means (Table X), Mann-Whitney U-Wilcoxon Rank Sum W Test(Table XI) , Kolmogorov –smirnov 2-Sample Test(Table XII), Wald-Wolfowitz runs Test(Table XIII).

The movement of fluids from the pulp towards the tooth apex occurs during cutting resulting from frictional heat of cutting, causing fluid expansion (BRANNSTOM M, LINDEN L, 1968[13]). Adequate cooling of a bur cutting at high speed is essential to prevent histological changes in the dentin and injury to the underlying odontoblastic region of the pulp. Temperature elevation can cause severe injury to the pulp, and coolants should be always used in cavity and crown preparation. Intermittent cutting using hand-piece with gentle pressure can minimize increase in temperatures during cavity and crown preparation. Dry preparation with high speed and use of anesthetic with vasoconstrictor are considered to be particularly harmful to the pulp. Provided adequate water spray is used during cavity preparation, displacement of nuclei will not occur (IVAR A.MJOR 2000[38]). The water during tooth preparation is required as coolant. It prevents the inadvertent raise in intra pulpal temperature, prevents desiccation of dentin and helps in flushing of debris during tooth preparation. Earlier studies show that an increase in intrapulpal temperature and surface raise of temperature occurs at cut dentinal tubules when water was not used as coolant.

This temperature raise due to dry preparation can cause pulpal injury. It is possible that a high surface temperature can thermally expand the dentinal fluid in tubules immediately beneath the poorly irrigated bur[59]. This may create shear force sufficiently large to tear cell membrane[24] and induce calcium entry into the cell[37]. An additional factor that may cause pulpal irritation is evaporative fluid flow[54]. This induces very rapid outward fluid flow in dentinal tubules[34,48] that would create shear stress across odontoblast and tear their cell membranes. Also the water will wash the cut debris reducing the smear layer formation on the tooth and reducing clogging of the bur, which also can raise temperature and reduce cutting efficiency causing pulpal damage. Also if no coolant is used, increase in intra pulpal pressure may occur which may damage the pulp.[25]

In this clinical evaluation of twenty teeth estimating clinical efficacy of aqua coolant in influencing the variation of pulpal temperature during tooth preparation, it was inferred that the use of aqua coolant posses a distinct and definitive advantage in diffusing thermogenesis and thermo propagation. The aqua coolant provided effective denomination of temperature variation in all phases of tooth preparation. The aqua coolant provided an effective additional buffer of 4.4257°F in thermogenesis , contrary to temperature variation during tooth preparation recorded in the absence of aqua coolant. Watson observed similar inference in 2000. This additional cooling negotiates for supplemental heat generation that may occur due to pressure exerted by various operators in different scenarios, varying abrasive effectiveness of burs used or a continuous tooth preparation devoid of pre-chilling protocol. This in vivo study had taken in to consideration possible heat dissipation due to pulpal blood flow, heat conduction to adjacent mucosa, teeth and bone, which were not a part of earlier in vitro studies.

The limitations of the study are that, histological evaluation after the procedure was not done. Other teeth like incisor molars canines were not studied. Racial and gender variations determining tooth dimensions were not considered. Intra pulpal temperature was recorded after perforation of the pulp. Also intra operator error for pressure application was not standardized. Further studies with bigger sample size and supporting histological observations are required. Advanced non-invasive techniques to measure intrapulpal temperature may be employed for future studies. Also other factors influencing temperature variation like rate and temperature of water flow, type and grit of bur in a in vivo setup need to be evaluated.

# SUMMARY AND CONCLUSION

Preservation of the pulpal architecture and its health is always the supreme biological objective during tooth preparation. Frictional heat generated at the bur tooth interface can elevate intrapulpal temperature and this elevation in intrapulpal temperature can deleteriously infringe the pulpal health thus contemplating an in vivo evaluation of the pulpal behavioral response to temperature variation.

This in vivo study on 20 premolars (maxillary/ mandibular) evaluated the variation in intrapulpal temperature during tooth preparation with and without the use of aqua coolant. This study also appraised the advantage offered by aqua coolant at every stage of tooth preparation with the aid of digital temperature indicator and thermocouple. The results of the study were tabulated and presented.

Within the limitations of the study following conclusions can be derived at:

(a). Use of aqua coolant produces 4.25°F additional cooling during tooth preparation as compared to without the use of aqua coolant.

(b). Intrapulpal temperature shows a regressive mode 7.27°F during tooth preparation with aqua coolant and 2.80°F during tooth preparation without aqua coolant.

(c). Intrapulpal temperature is 1.9° F lesser than intra oral temperature.

(d). Chilling effect of aqua coolant is most influential in reducing thermogenesis during groove type tooth preparation.

Thus this study endorses the effective application of aqua coolant in diffusing heat generation during tooth preparation and highlighting the relative efficacy the aqua coolant provides at every stage of tooth preparation.

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